SCOTTSDALE TRANSPORTATION COMMISSION REPORT

To: **Transportation Commission**
From: **John Kelley, Transportation Planner**
Meeting Date: **October 20, 2011**

ITEM IN BRIEF VEHICLE REPLACEMENT PLAN

Action: Information and Discussion

Background

In 2003 the City purchased seven new trolley vehicles, financed in part by the Federal Transit Administration (FTA) for the Downtown Route. The new vehicles were more modern than the previously used contract vehicles with air conditioning and wheelchair lifts. The trolley program has grown over time and is so successful that in 2006, the City added a second Neighborhood Route and purchased nine more vehicles.

In 2010, Valley Metro Route 76 was changed into a third City trolley route, the "Miller Road" Route, and six additional 30 foot low floor Eldorado transit buses were acquired from Valley Metro. In addition to the vehicles used for the three routes, up to four additional vehicles are used during high tourism season to shuttle visitors to the San Francisco Giants games at Scottsdale Stadium, and provide the seasonal Hospitality Route bringing visitors from resorts and residents to special events at WestWorld, the Tournament Players Golf Club and Downtown Scottsdale.

Today, the annual boardings on the city's trolley system exceed 900,000, and are anticipated to grow to over a million by FY 2022. The City vehicle fleet consists of 21 vehicles used to provide service on the three routes which serve neighborhoods and businesses in downtown and southern Scottsdale. In addition, the fleet accommodates the extra peak season services. According to Census data, areas north of Downtown Scottsdale exhibit a very low density of transportation disadvantaged individuals, whereas the areas south of downtown have the highest concentration of students, seniors, disabled, and Limited English Proficiency (LEP) citizens live. This makes the majority of transportation individuals in the area covered by the Trolley System routes. One area of exception is the area surrounding the Via Linda Senior center near the Shea corridor, which does show a of individuals higher concentrations of disabilities and/or over age 65.

FTA Vehicle Replacement Guidelines

FTA guidelines require transit vehicles to be replaced at specific time intervals and for operators to maintain a twenty percent vehicle spare ratio. The guidelines stipulate that the trolleys need to be replaced at 10 years of service and buses at 12 years. In 2013, seven trolley vehicles and six buses are due for replacement per FTA guidelines (see Table A).

Table A. Vehicle Fleet Age and Replacement Year

Vehicle	Year Placed in Service	Replacement Year	Number to Replace
7 Supreme Trolleys	2003	2013	7
6 Eldorado Busses	1999	2013	6
2 Supreme Trolleys	2005	2015	1
7 Supreme Trolleys	2006	2015	7

If vehicles are not replaced on schedule, breakdowns become more frequent, increasing maintenance costs and diminishing service quality. Last year the operator purchased a rescue wheel chair lift equipped van so when a trolley lift breaks down in the field, the passenger can be offloaded by hand and transported to their destination in the van. This has helped ensure the City is complying with Americans with Disabilities Act (ADA) guidelines.

Funding

Sufficient funds are programmed for vehicle replacement from Proposition 400 and FTA grants (Proposition 400 will be used to match FTA grants at 20/80% ratio). The Proposition 400 Transit Life Cycle Plan includes funding for the replacement of 7 trolley vehicles in FY13 and for the balance of the bus and trolley vehicles in FY2015. While the engine/fuel technology chosen will determine the cost of each vehicle (diesel, diesel hybrid, or natural gas LNG/CNG), the range is believed to be $450,000 to $650,000 each. The estimate for replacing the first thirteen vehicles is in the range of $3.5-5.0 million.

As we move to replace our existing fleet, we acknowledge that the existing trolley vehicles have served us well and were an improvement over the first generation of vehicles; however, newer designs will help us provide more comfortable and more accessible service to our customers, given the demographics of the audience we serve, at a lower cost per mile.

Considerations in Choosing Replacement Vehicles

In order to choose the right vehicle for Scottsdale's next fleet, several decisions must be made regarding vehicle size, engine, body style, fuel type and interior seating and materials. The attached report gives more detail on the vehicle choices available in terms of the many options available.

Vehicle Replacement Technical Summary Report

John Kelley
Transportation Planner
October, 2011

I. Current Operating Conditions

Currently 12 vehicles are used to provide service on three routes (Downtown (3), Neighborhood (6), and Miller Rd (3)). An additional, five vehicles are used for three months during peak tourist season (January – March) to provide service on the Hospitality Route, and to provide additional service on the Downtown Route for Spring Training games, Scottsdale Arts Festival and the Culinary Festival weekends. In addition, the FTA requires a 20 percent fleet spare ratio or an additional five spare vehicles on hand. In total, 21 vehicles are needed to provide the trolley service. Scottsdale has enjoyed continuous ridership growth on the system as route extensions and service efficiencies have been implemented. Table 1 below shows overall ridership trends.

The Downtown Route provides limited circulator service designed to bring residents and visitors to the downtown. The Downtown Trolley Route has had a ridership decline since 2009 when service was reduced from 10 to 15 minutes to meet the City's budgetary target. Previous to this service reduction, the Downtown Route ridership was growing. For two years following the service reduction, ridership growth declined and flattened. It appears that the route has growth potential if the economy improves or service frequency is reinstated. Growth could also be attained if the trend continues for growing attendance at special events and (Giants Spring Training, Culinary Arts, Taco Festival and events at Starwood located next to Marshall Way Trolley Bridge) or as parking constraints become an issue in the downtown area. The operation of only three vehicles on the Downtown Route is expected to continue for the next two to five years.

The Neighborhood and Miller Road trolley routes were designed to provide service to targeted audiences in Southern Scottsdale that are disproportionately either younger, students, elderly, physically challenged, low income or households with one or no vehicles. As indicated in Table 1, both routes have seen remarkable ridership growth. The Neighborhood and Miller Road routes provide much longer more traditional circulator service to community trip generators such as schools, parks, and employment centers as well as greater connectivity with Valley Metro fixed routes. Due to their popularity, crush loads now occur several times during weekday mornings and afternoons on both routes.

Ridership on the Miller Road Trolley has increased more than one hundred percent since the City changed it from Valley Metro Route 76 to a trolley route, and there is room to grow ridership even more. If service frequency was improved to twenty minutes as is the case on the Neighborhood Trolley, crush loads on the Miller Rd. Route would be eliminated and capacity expanded. This would improve ridership by an estimated twenty percent or more. Increasing the service frequency from 30 to 20 minutes would require an additional vehicle to be operated on the route, either during the peak hours or all day, and would increase contract costs by $150,000 to $300,000 per year. Operating additional vehicles during peak hours would eliminate crush loads and would only cost $30,000 - $50,000 per year and may also require an additional vehicle.

The Neighborhood Route has achieved a nearly 300 percent ridership increase during the past five years. Half of the growth can be attributed to a 2008 route expansion (see Table A). Judging by the ridership increases year over year, this route has been a success with the community and is operating at peak efficiency. If frequency were improved from 20 to 15 minutes, ridership could grow by twenty percent or more, however, two additional vehicles operated either during peak hours or all day would be required at approximately $350,000 or $600,000 annually.

Table 1 Five Year Ridership Summary

	2007	2008	2009	2010	2011	% Change
Downtown	169,744	200,067	*127,599	127,052	118,855	-31%
Neighborhood	140,490	390,987	524,601	524,480	552,590	+393%
Miller Road	**(108,496)	**(120,615)	***(96,211)	126,413	195,460	+201%
Total	310,234	591,054	652,200	777,945	866,905	+187%

* - 40% reduction in service to Downtown Trolley
** Miller Road was operated by Veolia Tempe as Route 76 and collected fares
*** Service cut eliminated Tempe portion of the route

II. Current Vehicle Fleet and Maintenance

The current 21vehicle fleet consists of fifteen Supreme trollies and six El Dorado National buses. While trolleys are used exclusively on the Downtown Route to achieve the most authentic look, the vehicles are interchangeable and each can operate on any route. All vehicles are thirty feet in length. The trolleys incorporate a high floor with a wheelchair lift, while the El Dorado's are a low floor vehicle with a wheel chair ramp.

The El Dorado buses were purchased by Scottsdale in 1999 for use on the Routes 66 and 76 and were operated by the Regional Public Transit Agency (RPTA) out of Tempe. These heavy duty vehicles have a twelve-year, 500,000-mile life expectancy and have

now reached, or are approaching, the end of their life expectancy. The buses have had a standard mid-life rebuild including a new/rebuilt power plant, transmission, suspension, steering, flooring, upholstery, and paint inside and outside. The buses use a different interior steel material which is more vandal resistant, in much better shape, and requires less maintenance than the specialized wood interiors of the trolley vehicles. The trolley interiors, while more authentic looking, are constructed of a less durable thin veneer wood surface which are being replaced, as needed due to cracking caused by high heat low humidity and vandalism.

Originally, the City purchased 16 trolley vehicles over four years, and placed them into service in 2003, 2005 and 2006. Trolleys are considered medium duty vehicles with a ten-year life expectancy. Unlike the heavy duty buses, there has not been a mid-life re-build, which means that five are at 90 percent, five are at 70 percent and five are at 50 percent of their mechanical life expectancy. One of the trolleys was taken out of service permanently as a result of a serious accident in 2008. The vehicle was purchased from the insurance company and was purchased by the contractor for salvage parts.

Operating the El Dorado buses has allowed the City to present to the public a low floor bus with the exterior appearance of a trolley. The vehicles were vinyl wrapped to look like the rest of the trolleys, but, offer the efficiency and comfort of a low floor, ramp-equipped bus that is safer, easier to maintain and more fuel efficient. It has also allowed the City to experiment using an alternative fuel that is less polluting than bio-diesel – Compressed Natural Gas (CNG).

The trollies are custom made vehicles and have no dealership network. Each one is essentially hand built, and each trolley differs slightly from the rest of the fleet. Parts must be sought ought through individual suppliers. Warranty work is diffused because there is no dealer per se. It .has been difficult and time consuming to have a warranty claim paid, because the sub providers tend to implicate each other for system failures. By contrast, the six Eldorado Buses offer standardized design/build, are warrantied, and, while under warranty, the dealership performs the work.

We currently spend more than $15,000 per month for parts and hundreds of labor hours to maintain our current fleet. In FY 2011, the total cost to maintain the fleet was in excess of $500,000. With higher maintenance needs also comes lower reliability of the transit service, since there is a greater likelihood that vehicles will be unable to run their routes or will have breakdowns in route. A major advantage of new vehicles is they come with warranties to cover component costs. New vehicles with extended warranties dramatically reduce operating and maintenance costs. This will help hold contract costs steady or minimize inflationary effects, allowing us to maintain current

service levels, or expand service, at a more stable fixed cost. As with all vehicles the older the vehicle becomes the more maintenance and repairs required and the less reliable they become.

Splitting the vehicle fleet into two types of vehicles (buses and trollies) with differing fuel, engine and body components, requires two distinct training programs for drivers and mechanics as well as two distinct parts inventories. At the time we obtained the buses from RPTA/Tempe to operate the Miller Road route, we were fortunate to have them available; however, it would be far more efficient if we could operate one vehicle that would fill the need for all routes, as was the approach when the city purchased the trolleys in 2003-06,

III. Chassis Component Considerations

There are many components and systems that make up a transit vehicle. This section presents information on the various components not associated with the drive train that will be available when replacement vehicles are chosen. These items affect the passenger's experience in terms of comfort, vehicle accessibility, and aesthetics.

High vs. Low Floor Design

When trolley vehicles transitioned from rail operation to rubber tires, the vehicle body was placed higher up on top of the larger rubber tired wheel and suspension system. Steps were added to bridge the higher floor level for boarding ease. This design approach is incorporated into the design of our current trolley fleet. Later, after the Americans with Disabilities Act (ADA) legislation was passed, wheelchair lifts were incorporated into the high floor design either at the back of the vehicle or, as in the case of our vehicles, out of the rear door integrated into the steps. The integration of the lift into the rear steps requires several hinge points, a separate hydraulic and electrical system and an increase in maintenance and an increased failure rate.

The high floor design coupled with the vehicle width and interior configuration limits the amount of seating, seated legroom, and standing room compared to a traditional low floor design. It also requires passengers who cannot climb steps or that cannot use mobility devices to always use the lift, resulting in longer loading times. The high floor also raises the vehicle's center of gravity, which can impact stability.

The buses are designed with a curb-height floor, which allows for boarding/de-boarding of passenger's level with the sidewalk, making ingress and egress not only faster but safer. Since the three trolley routes provide service to areas in the City with high senior and disabled populations, low-floor design vehicles would improve access. When the

loading floor is at curb level, the most complex and unreliable sub-system on the existing vehicles, the wheel chair lift, is replaced with a simple ramp.

Seating and Vehicle Capacity

The capacity of three vehicle types is shown below in Table 2. Trolleys have low back, flat wooden seats with abrupt edges. Seating is symmetrical. Buses have high- backed, upholstered seats and contoured edges. Seating is asymmetrical and designed to keep passengers in place without seatbelts. Buses offer greater seating capacity, as well as greater standing capacity, due to the asymmetrical seat configuration. Some of the seating in the trolleys also has very limited foot room. Perimeter seating on the trolleys, where all seats face inward, increases seating capacity but makes travel uncomfortable for some passengers that cannot sit perpendicular to the travel direction without experiencing travel sickness. Others are unable to turn their heads to face the front of the vehicle due to neck issues. Both types of vehicle turn some benches/seats facing inward, so they can be folded up to accommodate wheelchairs.

Smaller vehicles known as cutaways, like those used for the Tempe Orbit, have fewer seats and little standing room compared to trollies and buses. As shown by the table, during peak hours our vehicles are at or near capacity. The option for using smaller vehicles is discussed later in section VI.

Table 2 Vehicle Capacity by Vehicle Type

Capacity	Miller 7-8 AM Peak	Miller 4-6 PM Peak	NH 7-8 AM Peak	NH 4-6 PM Peak	Cutaway	Trolley	Bus
Seated	25	25	25	25	17	22	25
Standing	20	25	15	15	6	22	25
Total	45	50	40	40	23	44	50

Wheelchair Lift vs. Ramp

The trolley vehicles use a wheelchair lift while the buses use a ramp. The most current lift technology was designed in the early 1970's and includes electric, hydraulic and mechanical systems to fold three stairs into a flat platform that raises and lowers to street level. Ramps came into being with the low-floor vehicle design. Lifts are much more complicated and difficult to maintain and operate. Regardless of the design or maintenance, all lifts start and end with a shake or bump, which is disconcerting to a person using a mobility aid and intimidating to a person using a walker. In the event of lift failure, when a passenger onboard desires to exit the vehicle and can't use the steps, the use of a rescue vehicle or a Fire Department call is required.

Low floor buses have ramps that are also operated electrically, but they have only one moving part which unfolds to provide a ramp to the curb. The ramp is very reliable and, even if a failure occurs, the operator can deploy it manually. The ramp is shorter than the lift, and would be an improvement for operating in narrow confines of Old Town Scottsdale and older neighborhoods with narrow streets and sidewalks. The ramp angle meets ADA guidelines to be accessible for motorized and non-motorized mobility devices. The bus ramp is inherently safer as the passenger's mobility device is never more than six inches off the ground compared to four feet with the trolley lift. The low floor ramp is also significantly faster to operate for both passenger and operator which is a key factor in schedule adherence.

Using the buses with the ramp to provide service on the Miller Rd. Route provided an opportunity to compare the ramp with the lift. As the Miller Route ridership dramatically increased over the past two years, the floor and lift design has facilitated more efficient boarding/de-boarding and improved on time performance.

Vehicle Management System (VMS)
VMS use Geosynchronous Positioning Satellite (GPS) technology to provide vehicle location within thirty feet of actual. This allows tracking of the vehicle whenever the engine is operating to provide real time information for Valley Metro's new My Stop program, and also verification of Route Schedule Adherence (RSA) to verify early/late issues. Included with VMS package are ADA requirements such as visual signage inside the bus for hearing impaired to display current stop and destinations. Neither trolleys nor buses currently have VMS.

Alarm and Announcement Systems
An Automated Voice Annunciation (AVA) feature provides an audio announcement of current stops and destinations (both inside and outside the bus) for visually impaired passengers. Maintenance software features monitor and display warnings for all engine/drive train sub-system maintenance issues including preventive maintenance issues to the operator as well as to the dispatcher or maintenance consoles. An emergency alarm system (silent on the bus) will notify the dispatch console in event of an emergency, with the capability to listen to the events on the bus from a remote console. A security camera system can be included to monitor operator performance as well as provide pre-post incident evidence inside and outside the bus.

Air Conditioning vs. Open Air
Due the local climate, Scottsdale requires a heavy duty roof mounted A/C with maximum cooling capacity to deal with desert heat/humidity and the continuously

opening vehicle doors. The Downtown trollies have operated with the windows removed in the past. If the windows are removed in the spring and fall, the plastic roll up curtain that is subject to heat damage and cumbersome to install and operate has to be removed. Windows have not been removed the last three seasons and no complaints or requests have been received. Larger windows are now available that can be opened to provide open air experience in spring and fall and would avoid the issues with the plastic roll up curtain.

Vehicle Interior

Newer products are available that retain much of the authentic trolley appearance while minimizing maintenance. For example, brass handrails can be replaced with a one piece “same look” brass finish unit, eliminating polishing as well as the constant replacing and tightening of the screws. Interior walls can be covered either with an anti-graffiti brass finish metal, a wood veneer finish covered in a plastic anti graffiti outer coating, or a wood looking plastic anti-graffiti product. Floors products are available in a much larger variety of colors and can now be better matched to the interior products, instead of the institutional grey or black often seen.

Display areas would be available for car cards (12”x 30” cardboard/light plastic signs) and can run the length of the passenger compartment. These are used for Public Service Announcements or sold as advertising. Display racks should be incorporated into front dash, package shelve (front right wheel well), and privacy panel (panel behind the operator.

Vehicle Exterior

Exterior skin materials are available in composite or metal products, preferably modular in design to provide fast and easy repair/replacement in the event of body damage. Ideally the skin would be flat, free of rivets and body moldings. The exterior on the existing trolley vehicles is more expensive to buy and more expensive to maintain. A smooth sided bus provides opportunities to use vinyl wrap to give the appearance of a trolley as we are now doing, or it can provide a canvas for advertising opportunities as was used on the Hospitality Trolleys.

Lighting and Head Sign Systems

The current trolleys have no signage and use plastic signs on the dash board. The electronic head signs, side signs and rear signs available on newer vehicles provide highly visible notification of route and direction of travel for passengers and motorists from all angles. The rear signs can now be programmed to notify motorists following a trolley that the trolley is boarding or de-boarding a passenger using the lift or ramp.

Lighting for both interior and exterior should be Light Emitting Diode (LED) type, which provides more and clearer lighting as well as eliminating the need to replace bulbs during the life of the vehicle. LED technology will eliminate the need to change bulbs for the twelve year life expectancy of the vehicle.

Passenger Counters

Automatic Passenger Counters (APC) can be included on vehicles. Vehicles equipped with APC have a series of undetectable lasers that record boarding/de-boarding using GPS and an atomic time clock to record passenger origin and destination. This data is invaluable in establishing routes, schedules, frequency and future route planning, and measuring route productivity. Not all vehicles need the passenger counters, as those with APCs installed can be rotated amongst the routes to conduct counts.

IV. Drive Train Related Components

There are a number of options and choices for replacement vehicles based on different fuels and engine design: diesel, bio-diesel, Compressed Natural Gas (CNG), Liquefied Natural Gas (LNG), electric and hybrid diesel. This section discusses each fuel/engine combination in context with the environment the trolley system operates in. Additional information on other drive train components is also discussed.

Gasoline

Gasoline engines have the shortest engine life in our environment because the trolleys, especially in the Downtown, operate at low speeds with a great deal of idle time. The durability of the gas engine is significantly shorter than Diesel or CNG/LNG, engine temperature is higher, and the fuel mileage is equivalent or less than a diesel. Gasoline is also less safe as a fuel than diesel as it ignites very easily. Gas engines are sufficient for smaller vehicles with less carrying capacity than Scottsdale's passenger loads during peak hours.

Diesel

Diesel engines, compared to Gasoline engines, are more fuel efficient due to the way fuel is injected and ignited in the cylinder, and diesel fuel has an 18 percent higher energy density than gasoline. The combination of more efficient engine design and more productive fuel results in better all around fuel efficiency for diesel engines.

Diesel fuel is considered safer than gasoline because it is less flammable. In terms of the environment, diesel emits very small amounts of carbon monoxide, hydrocarbons and carbon dioxide. In the past, high amounts of nitrogen compounds and particulate matter (soot) were released from burning diesel fuel. In 2010 the clean diesel Federal mandate became effective eliminating emissions by more than 80 percent. New technology incorporates the use of: cleaner fuel (low sulfur diesel), improved

combustion technology with use of post combustion urea treatment, and the addition of improved particulate traps. Diesel engines are more durable and require fewer component replacements during their lifespan reducing the maintenance costs. When the added cost for a diesel vehicle is considered in the lifetime cost to own, they are a less expensive choice over gasoline and CNG/LNG. Diesel buses currently yield 3.5 to 4.5 miles per gallon.

Bio-Diesel

Bio-diesel fuel is produced from domestic, renewable resources like rapeseed or soybeans. While biodiesel contains no petroleum, it can be blended at any level with petroleum diesel to create a biodiesel blend. Our current trolley fleet uses 80 percent biodiesel blend. Bio-diesel provides all the benefits of diesel engine design with the additional benefits of being an alternative fuel. This fuel is cleaner burning, recycles a waste product and is eligible for Federal Grants as an alternative fuel. Since the fuel is burned in a traditional diesel engine, no additional capital or training costs are required. Currently all the trollies are bio-diesel and obtain 4.0 to 4.5 miles per gallon in the trolleys. The energy output of the fuel per gallon is only slightly less than that of Diesel.

New bio-diesel vehicles will be required to meet the new more stringent 2010 Federal Emissions requirement. Most manufacturers are using an additive DEF (Diesel Emission Fluid) which is injected after combustion into the exhaust and re-ignited in the particulate trap (similar to the catalytic converter on a car). According to current data, DEF is more expensive and is consumed at a much higher rate than anticipated. One manufacturer, International, is using a twin turbo configuration to burn fuel more completely in the combustion chamber. While all diesel engines are turbocharged, in the Scottsdale operating environment where trolleys operate at idle and very slow speeds turbochargers are under extreme stress and have a short lifespan. Adding a second turbo charger is likely to increase maintenance costs, but eliminates the urea cost.

Scottsdale provides bio-diesel fueling stations at both North and South Corporation yards. We fuel bio-diesel trolleys at the South Corporation Yard (1.2 miles from current contractor's facility) and, if needed, the contractor could install a movable bio-diesel fueling station on their site.

CNG

Engines running on Compressed Natural Gas (CNG) are quieter and have lower emissions output than diesel including nitrogen oxide and CO_2. CNG also qualifies for the Federal Alternative Fuels credit. Application of the fuel credit makes this fuel the least expensive; however, the future of the Federal Alternative Fuels credit, which must be re-authorized by Congress every year, is an annual unknown. If the credit is

eliminated, CNG would become the most expensive fuel on a “miles per gallon” equivalent basis.

CNG is stored under pressure and, as the ambient air temperature warms, the gas expands and the fuel is vented (released into the atmosphere). In this manner, fuel is lost when the bus is parked, with losses increasing when the outside temperature is high (above 90-100 degrees Fahrenheit). CNG also uses more fuel at idle than at operational speed. Fueling and maintenance procedures for CNG vehicles would require some additional staff training. This fuel yields 2.0 to 3.0 miles per gallon in a thirty foot bus.

Currently fuel the CNG El Dorado buses at East Valley Bus Operations Maintenance facility in Tempe. This requires contractor staff to drive the bus approximately twenty-five minutes each way and we can only fuel during mid-day. Scottsdale does have CNG pumps at the North Corporation Yard, but has limited dispensing options (twelve slow fuel stations to accommodate larger vehicles, and one fast fuel station to serve cars and light duty trucks). Utilizing the North Corporation Yard fuel site would increase fueling costs, because it is outside the operating areas of all three trolley routes and would require the contractor to use additional staff to drive to/from the fueling station. In addition, CNG fuel delivery takes longer than the time to fuel a gas or diesel vehicle. One option would be to provide an additional CNG fueling station; however, that would involve a large capital expenditure including electronic gas monitoring, ventilation and warning systems.

LNG

Liquefied Natural Gas (LNG) provides a quieter power plant and is an alternative fuel with a Federal Alternative Fuel credit making this the most inexpensive fuel. As noted above, the Federal Alternative Fuel credit must be re-authorized by Congress every year. Without the fuel credit, LNG is the most expensive fuel. Neither the City of Scottsdale nor the contractor has LNG fueling capabilities, and the nearest fueling station is in Mesa or Sky Harbor Airport. Installation of an LNG fueling station would require very large capital costs including electronic gas monitoring, ventilation and warning systems. LNG is also stored under pressure. As the ambient air temperature warms, the gas expands and the fuel is vented (released into the atmosphere), so fuel is consumed when the bus is parked. LNG also uses more fuel at idle than at operational speed. LNG buses operate at lower engine temperatures.

LNG is the slowest and most complicated dispensing operation. This would dramatically increase fueling costs, because it is outside the operating areas of all three trolley routes and would require staff to drive to/from fueling station. LNG is also the

most challenging fuel to manage because it is dispensed at –200 degrees F and is extremely dangerous if it contacts human skin. LNG would require additional staff training. This fuel yields 1.5 to 2.0 miles per gallon in a thirty foot bus.

Electric and Hybrid-electric Diesel

Single source electric rechargeable vehicles are extremely quiet but do not have the range of other power sources. Previously, such vehicles could not provide enough cooling for the desert climate. A new vehicle is in the prototype testing phase at two jurisdictions and has no long term operational experiences. The vehicles cost $1,000,000 and require an on-street charging station which costs an additional $350,000 or $1,000,000 (slow vs. fast charge). This system would require at least one battery change within a twelve year lifecycle at an estimated cost of $250,000 per change. Changing to this completely different technology would require additional training costs, as well as operational changes.

A hybrid-electric vehicle has two power sources used separately or in combination - the electrical energy storage device such as a battery pack, supercapacitor or flywheel, and the auxiliary power unit (APU) or internal combustion engine, turbine or fuel cell. For transit vehicles today, only the diesel-hybrid is available. There are several different manufacturers using differing hybrid-electric technology, including: series, parallel or dual mode, engine or battery dominant, and charge sustaining or charge depleting. Hybrid-electric vehicles contain a single or multiple electric motors that provide power to the wheels. Power to the motor is provided by either the energy storage device or the APU, or in combination, depending upon the type of hybrid-electric vehicle. The vehicle's computer constantly monitors the battery state-of-charge to determine if engine operation is needed to recharge them. Because the bus does not rely on the engine for its peak power output at the axles, the hybrid bus uses a smaller engine (often pickup truck size) which results in better fuel efficiency - and the potential to lower emissions.

Tables 3 and 4 illustrate the fuel efficiency factors and the environmental emissions of each fuel reviewed above. The trends to be noted from this data are that emissions between diesel and bio-diesel engines are relatively similar. They vary from CNG engines by producing more CO_2 and NO_x emissions with slightly more particulate matter; however, they produce significantly less non-methane hydrocarbons. CNG actually has the lowest emissions per gallon used; however, due to lessened fuel economy, this effect would be negated and in some cases reversed. Similar issues affect gasoline engines. Due to the fact that they are smaller cut away vehicles, more vehicles are required to operate at any given time (doubling route mileage), so their emissions and economy must be doubled in comparison. Hybrid bus engines operated

by other west coast properties are achieving a 20 percent improvement in fuel economy.

Table 3 Comparison of Fuel Types, by Efficiency per Gallon Equivalent

Fuel	Power (BTU) Produced	2011 Cost	Safety Factor	Efficiency (mi/gal)	Overall Efficiency
Gasoline	114,000	$3.25	Low	4.5	Low*
Diesel	138,000	$4.05	High	4.0	High
Bio-Diesel (B20)	135,613	$4.05	High	4.0	High
Diesel Hybrid	138,000	$4.05	High	4.8	High
CNG	138,000	$1.50	Med	3.0	Moderate

*Based on vehicle capacity (twice as many vehicles are operated)

Table 4 Emissions by Fuel Type Comparison

Fuel	CO_2 g/ gal	NO_x g/ mi*	PM g /mi*	NMHC g/mi*
Gasoline	8,482	**	Not regulated	**
Diesel	10,274	4.58	0.028	0.12
Bio-Diesel (B20)	9,748	4.73	0.022	0.11
Diesel Hybrid	8,527***	3.80***	0.023***	0.10***
CNG	7,517	2.84	0.023	0.84

***Central Business District Cycle (operating environment)

**** Very little data is available comparing gas engines and cutaway vehicles to those used by transit buses. It is worth noting that NO_x emissions are typically significantly higher in gasoline engines when compared to diesel counterparts.

***Based upon an approximated 17% increase in efficiency derived from data from Santa Barbara fit to our climate (added air conditioning season).

Source: Clark, N., Zhen, F., Wayne, W., & Lyons, D. (2007, July 02). *Transit bus life cycle cost and year 2007 emissions estimation*. Retrieved from http://www.proterra.com/images/WVU_FinalReport.pdf

Front Mount vs. Rear Mount Engines

The majority of heavy duty buses contain rear mounted engines for several reasons. There is a better work environment for the bus operator, because the noise and heat of the engine is in the back and not in the driver's compartment. Passengers also benefit, because the engine heat/noise is behind them. Passenger access is reduced in a front engine vehicle due to the intrusion of the engine cover and the lack of a rear door.

A rear mounted engine is easier to access for maintenance than front mounted engine. Since the engine is typically the heaviest component of the bus, putting it near the rear axle usually results in more weight over the rear axle than the front, commonly referred to as a rear weight bias. The farther back the engine, the greater the bias. Since rear weight bias reduces forward weight transfer under braking, and increases rear weight transfer under acceleration, a rear mounted engine facilitates better braking and acceleration. Vehicles that need to make rapid stops and starts, similar to those occurring on the Downtown Route, benefit from rear mounted engines. Traction is more evenly distributed among all four wheels under braking, which accommodates shorter stopping times and distances. When accelerating, the driven wheels have increased traction, allowing them to put more power on the ground and accelerate faster.

Transmissions

A six speed automatic transmission is the industry standard and provides smooth efficient shifting for both passengers and operators and for maximum fuel efficiency. Transmissions currently being used on our existing trolley and bus vehicles are three speed automatics. While there have been no transmission issues to date with either of our vehicle types, the improved gear ratios offered in the new transmissions will provide smoother take off from a stop and may increase fuel efficiency to a minor degree.

Electric Sub Systems

An engine sub-system removes all ancillary systems (air conditioning/ventilation, engine cooling fans/water pump, etc.) and places them on an independent system to operate. This creates greater fuel efficiency, plus longer engine and oil life, by removing drag on the engine and allowing it to run cooler.

VI. Vehicle Replacement Considerations

There have been suggestions over the years that we consider operating smaller vehicles such as the Dial a Ride Vans or cutaways (smaller vans with an enlarged fiberglass body) like those used for the Tempe Orbit system. Both these vehicle types have a high floor and require the wheel chair lifts to be placed in the doorway at the rear or rear side second entrance. This requires passengers to enter and exit through the front door only, as a third door would reduce seating significantly. The combination of single door operation, slower and less reliable lifts, and less capacity would necessitate

the operation of additional vehicles on each route. Adding vehicles requires the addition of drivers, which affects operating costs. The most expensive part of trolley operations is labor costs: operators, servicing (cleaning and fueling), mechanics, administrative, and supervisory staff. Additional vehicles would mean higher operating costs for the additional drivers needed for peak hour vehicles and also higher maintenance costs.

While the cost to purchase smaller vehicles is attractive, the engine life span is shorter, more of them are required for the fleet, and they will need to be replaced more frequently. An assessment of the cost difference between operating a fleet of smaller cut away vehicles vs. larger trolleys or buses was made and is shown in Table 5 below. The evaluation is based on an estimated conservative ridership increase of two percent per year. Based on this ridership analysis, the fleet size required would not change over the next ten years.

The data shows that if the existing vehicle fleet were replaced with smaller cutaway vehicles the total number of operating hours and maintenance (which is the basis of the contractor's reimbursement) would increase due to the larger fleet needed to accommodate ridership and peak hour loads. The table illustrates that while smaller vehicles may seem more appropriately sized for downtown and some residential areas, the contract operating costs increase quite dramatically at the end of the ten-year period. This is primarily due to the fact that a driver costs the same regardless of the vehicle size they are operating, and the increased number of drivers needed to operate the smaller vehicle fleet. In addition, the smaller vehicles last on average three years compared to ten years for the larger vehicles.

Table 5 First and Ten Year Comparison of Vehicle Type, vs. Operating Costs
(Based on annual 2% Ridership increase, Gas Cutaway, and Diesel Bus)

	First Year		Ten Year Total	
	Cutaway	**Bus or Trolley**	**Cutaway**	**Bus or Trolley**
Route Hours	100,317	54,234	100,317	54,234
Drivers Required	48	26	48	26
Vehicles Required	26	18	26	18
Maintenance Cost	$234,000	$162,000	$3,328,000	$4,500,000
Operating Cost	$1,504,800	$813,500	$15,074,500	$8,114,310
Total Operating Cost	$1,738,800	$975,500	$18,402,500	$12,614,310
Capital Cost (City's 20% Match)			$3,120,000	$1,620,000

The expansion of the trolley system with the Miller Road Trolley (formerly Route 76) has proven the value of operating buses in lieu of trolley vehicles. The buses have a low floor which aligns with the sidewalk making boarding and de-boarding not only faster, but safer for our passengers, especially our seniors. The buses have a wheel chair ramp that has one moving part, which is not only faster and more reliable and it can be operated manually in the event of failure. This eliminates a vast majority of ADA issues. Buses also provide more passenger amenities such as upholstered seats, wider aisles, leg room. Buses also provide a single source for warranty claims, improved manufacturer's support of maintenance such as manuals, electrical schematics, manufacturers training and web sites, all lacking with the trollies.

Options for buses include trolley like interior/exterior packages from the factory, or using the vinyl wrapping to provide trolley appearance as we did with buses on the Miller Road Trolley (formerly Route 76). This would be the preferred option as it reduces maintenance issues and provides a flat surface for advertising opportunities. The riding public did not typically differentiate the vinyl wrapped buses from the existing trolleys until stepping inside. Based on customer contacts from Valley Metro and phone calls and e-mails to staff, the riding public prefers the bus to the trolley.

Due to the small number of vehicles in the fleet, it is operationally difficult to maintain different sizes and types of vehicles for different route applications. It is much more desirable to have one vehicle that can perform on all three routes.

Another option for solving the peak load issue on the Neighborhood and Miller Routes previously discussed would be to replace some of the fleet with longer 35-foot vehicles instead of the 30-foot. The same 30-foot vehicle is also available in a 35-foot version using the same drivetrain and chassis components for fleet compatibility. The vehicle also has the same wheel base. The longer vehicle would also maintain operating costs at their current level while minimally increasing the vehicle cost. Each vehicle would increase carrying capacity by approximately 15 passengers.